

Knowledge Cultures and the Shaping of Work-based Learning: The Case of Computer Engineering

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Abstract This paper examines how the knowledge culture of computer engineering – that is, the ways in which knowledge is produced, distributed, accumulated and collectively approached within this profession – serve to construct work-based learning in specific ways. Typically, the epistemic infrastructures take the form of information structures with a global outreach that both hinge on and generate standardization and codification. At the same time, computer engineering implies extensive engagements with technological objects that are open-ended and in constant transformation, such as systems, programs and codes. The professional domain is thus characterised by a richness of what may be termed ‘epistemic objects’, that is, objects marked by their unfolding and question-generating qualities. The paper reveals how these features involve engineers in multiple and coexisting dynamics of objectual practice that provide and constitute opportunities for learning. The paper concludes by discussing some implications of this knowledge culture for individuals and communities alike.

Keywords Knowledge cultures · Work-based learning · Computer engineering · Epistemic objects · Objectual practice

Introduction

Issues of learning are brought to the forefront in today’s society. Rapid shifts in knowledge and institutional arrangements call upon individuals and communities to engage in never-ending processes of learning and relearning. Moreover, rich opportunities for learning are seen as a key to securing wealth, welfare and self-fulfilment among policymakers as well as employers and employees. The contemporary notions of learning as ‘lifelong’ and ‘lifewide’ position learning as a

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key activity over the lifespan and in life as a whole, private and leisure activities included. Further, the individual is placed at the heart of the debate and presented for ideals in the dual form of demands and opportunities. Researchers point to how notions of learning are linked to political and economical issues and serve as powerful means of governing, by producing new kinds of identities for individuals to take up, as well as tools to support individuals in these efforts (Edwards 2004; Olssen 2006; Tuschling and Engemann 2006; Usher and Solomon 2001). A space of reasoning is created in which individuals are mobilized in particular ways and asked to embrace the notion of the continuous learner as a core narrative of identity construction. As Edwards (2004, p. 435) describes the current state; “A learning subject is one who adopts a learning approach to life as part of the care of their self”.

When it comes to professional life, a number of initiatives have been enacted to secure practitioners’ opportunities for continuing professional development. In some countries, efforts take the more formal character of compulsory engagements (e.g. in the UK, where professional development typically is linked to professional standards and quality assurance, and framed within an overarching framework of qualifications initiated by the government¹), while other countries frame their efforts within a rhetoric of rights (e.g. in Norway). In any case, learning in working life is not only about participating in preset programmes or meeting formal requirements. It is also about deliberate practices of self-conduct in which professionals engage in processes of improvement and further exploration of knowledge on a discretionary basis. Modern professionalism allocates extensive responsibilities to individual practitioners as to commit themselves to a lifelong learning process and to maintain currency in their domain of professional expertise (Friedman and Phillips 2004; Nerland and Jensen 2007). Further, perhaps for most professionals, learning is tightly integrated in and appears as a valued outcome of their everyday work (Billett 2004; Collin 2005; Eraut 2006). As noted by Eraut (2000), the practitioners’ role in seeking learning opportunities while practicing work is significant for the degree and quality of learning in the workplace. Thus, the informal and deliberate dimensions of learning in working life need to be further considered and explored.

In this respect, the character of the knowledge domain is a powerful but often overlooked factor. Learning processes in working life are constituted in distinct ways relative to the enterprises and domains of knowledge in which they are embedded. Particularly in professional work, which is based on expertise in specific domains, the ways of structuring and organizing knowledge in the professional field are significant factors for learning and identity formation. At the same time, these structures are enacted by individuals and dependent upon individuals’ engagement. Relationships with knowledge, therefore, have both regulative and agentic implications, and the organization of a knowledge domain provide resources

¹ For instance, The Health Professions Council has launched standards for continuing professional development (CPD) in their field and states that “all registrants must undertake CPD and are expected to show evidence of their learning and the outcomes of this” (Health Professions Council, 2006: Continuing Professional Development and your registration. London) Similarly, in the field of engineering, the Society of Operative Engineers poses evidence of CPD as a requirement for membership (<http://www.soe.org.uk>).

through which practitioners negotiate their competencies and form their professional lives (Billett et al. 2005).

The field of computer engineering is an interesting case for several reasons. As a domain of expertise that echoes core descriptions of the network society (Castells 1996) changes in knowledge practices may manifest themselves earlier in this field than in many other professions. One example is the emphasis given to global information structures, which reflect the quest for transparency that increasingly characterises knowledge production in today's society (Knorr Cetina 2002), with implications for learning that will be discussed below. Further, computer engineering may be said to precede current change processes within the professional sector. Practitioners in this field are involved in activities that override local communities and cross traditional distinctions between professional work and economic markets. Thus, they exemplify movements in the professions as described by Brint (2001), who depicts how the professional sector becomes tightly linked to the so-called 'knowledge economy' in ways that exceed the boundaries of local production. Taken together, the field of computer engineering incorporates core dimensions of the knowledge society, both where knowledge practices and organizational issues are concerned. Interestingly, these trends seem to be accompanied by an increasing concern for considering computer engineering as a professional discipline, grounded in a collective domain of knowledge and a profession-specific ethos for engineering work. For instance, central representatives for the field of software engineering have initiated discussions and efforts to developing this field of expertise into a recognized profession, by strengthening and making explicit the foundation of professional practice in a shared domain of knowledge and values (Thompson and Edwards 2001). Another example is the recent call for professional standards in web design, for instance as manifested in the establishment of the Web Industry Professional Association in Australia (<http://wipa.org.au/>).

Drawing on data from the Norwegian research project *Professional learning in a changing society* (2004–2008), this paper examines work-based learning among Norwegian computer engineers in relation to the knowledge culture of their profession. It focuses on addressing the following questions: How does this knowledge domain and its interrelated knowledge practices serve to shape work-based learning in specific ways? And how do engagements with knowledge objects provided in this culture involve the engineers in cycles of learning? In order to explore these questions a theoretical framework will be utilized which draws on the notions of epistemic cultures and objectual practice introduced by Knorr Cetina (1999, 2001). It should be noted, however, that whereas Knorr Cetina (1999) first invoked her concepts from studies of knowledge production in the sciences, the present paper uses her ideas as sources of inspiration in exploring the knowledge culture of a profession. Consequently, this paper does not use the concept of knowledge in a strict foundational sense. Instead it employs the term knowledge practices to refer to the utilization, enactment and advancement of different expressions of profession-generated knowledge, and gives special attention to their ways of influencing work-based learning. This is also in line with Knorr Cetina's more recent argument (2001, 2002, 2006) that in the era of the knowledge society, the general significance of scientific knowledge is increasing and its principles of social organization permeate into other areas of society. As she states, the transition

to knowledge societies “involves the presence of knowledge processes themselves (...), it involves the presence of epistemic practice” (Knorr Cetina 2001, p. 177). She explains this by pointing to how many areas of social life depend on symbolic representations of knowledge and involve practices that relate to analysis and representations of the world in which they engage. Thus, “understanding knowledge societies will have to include understanding knowledge practices” (ibid.). The professions are among the social spheres where knowledge practices are produced and performed.

Knowledge Cultures and Their Manifestations

Professional communities are constituted through their specific ways of engaging with knowledge. The expressions of knowledge in use, the artefacts and tools provided for professional practice, the traditions and methods of knowledge production and the collective models for knowledge application serve to give communities an integrative power. For instance, ways of relating to knowledge underpin the fostering of collective identities and commitment to quality standards in a community. In order to grasp these functions, however, it is necessary to approach professional knowledge from a dynamic and practice-oriented perspective. Professional practice rests on a collective base of knowledge, but will at the same time contribute to the development of this knowledge base through the ways knowledge is explored and performed in professional work. Thus, the relationship between disciplinary knowledge and the practices in which such knowledge is enacted may be described as a mutually constitutive one (Becher and Trowler 2001; Knorr Cetina 1999).

As regards the formation of work-based learning, some organizational aspects of knowledge domains are of special interest. Firstly, the ways in which knowledge is produced is constitutive of the knowledge domain. For instance, professional communities differ in the extent to which their collective ways of knowing rest upon scientific achievements, upon personal experiences and reflexivity, or upon processes of codification. The general processes of knowledge verification are interlinked with these issues. A second dimension relates to the ways in which knowledge is accumulated. This aspect concerns the extent to which knowledge is regarded as cumulative in character and built up in a linear way, by adding experiences or pieces of information to each other in a hierarchical structure. It also concerns the extent to which accumulation is seen as a collective and collaborative project or as an individualized matter of gaining rich experiences. Thirdly, the ways of distributing knowledge within the professional community is a distinguishing aspect that is closely linked to the character of the epistemic infrastructures provided. These may, for instance, be more or less locally bounded, more or less technological in character, more or less based upon the written language, and so forth. For instance, some professional communities are deeply influenced by the use of electronic devices that links local work to other practices and institutional levels, while others rely heavily on human interaction and the sharing of knowledge among practitioners who are physically co-present. Fourthly, the profession-specific patterns of accessing knowledge and ways of handling the relationship between general

knowledge advancements and its application in specific work settings are a constitutive dimension in professional knowledge cultures.

In practice, these dimensions mutually shape each other and operate together in structuring both work practices and approaches to learning. They form the discipline-specific temporal and spatial organizations of knowledge which constitutes the professional field and which also provide the ground for introducing newcomers to the professional practice (Nespor 1994). In other words, they form the *epistemic culture* of the profession which, borrowing the words of Knorr Cetina, may be defined as

those amalgams of arrangements and mechanisms—bonded through affinity, necessity, and historical coincidence which, in a given field, make up how we know what we know (Knorr Cetina 1999, p.1).

She points to the formative aspects of knowledge processes and utilizes the metaphor of ‘knowledge machineries’ to illustrate how the different arrangements and mechanisms work together to constitute a certain domain (ibid.). Further, as Knorr Cetina points out, these machineries are not only constitutive of knowledge but also of the knower. Practitioners are shaped through and learn to see the world through the lenses of their knowledge culture. Thus, she relates knowledge cultures to styles of thinking, believing and acting:

By a knowledge culture I mean (...) an ‘epistementality’ of particular beliefs about, for example, the correct distribution of knowledge, the naturalness of access to it, the particular ways knowledge should be handled and inserted into personal and organizational life. Such epistementalities also take form as particular organizational arrangements of roles and agencies. (Knorr Cetina 2006, p. 37).

Following this line of thought, professional knowledge cultures can be regarded as ‘collective mentalities’ that both express themselves in certain practices and are made possible through the ways in which knowledge is organized and (collectively) engaged with. However, this does not, mean that knowledge cannot be something ‘real’; something materialized, something objectified and something subjected to consensus. On the contrary, it is in processes of materialization, articulation and codification that ‘epistementalities’ as ways of understanding and dealing with knowledge manifest themselves; that they are brought into play, continued and subjected to advancement. By examining how knowledge is mediated by artefacts and collective practices, how these tools and activities are organized in time and space, how they are linked up with other structures of collective action and how they invite certain kinds of engagement, we may reveal how work-based learning activities of practitioners are encouraged, directed, and perhaps restricted in certain ways.

Knorr Cetina (2001) has contributed further to the understanding of knowledge practices by her notion of *objectual practice*, that is, forms of practice that are spurred by the dynamic interplay between humans and their non-human material. Drawing on Rheinberger (1997), she points to how practices in today’s society increasingly take an epistemic character, and employs the concept of *epistemic objects* as a means to understanding how such practices are generated (Knorr Cetina 1997, 2001). She contrasts epistemic objects from definitive and thing-like entities,

and defines the former as characterised by their question-generating character and their lack of completeness of being:

Since epistemic objects are always in the process of being materially defined, they continually acquire new properties and change the ones they have. (Knorr Cetina 2001 p. 181).

Epistemic objects are thus characteristically open and complex, and when individuals attempt to reveal them they typically do so by increasing rather than reducing their complexity. By means of these qualities, epistemic objects have the capacity to promote learning by providing a sense of excitement and signalling ways to explore their not-yet-fulfilled potential (Knorr Cetina 1997; Jensen 2007).

In the context of professional practice, Knorr Cetina's perspectives brings to the fore a notion of epistemic objects as unfolding structures of lack and temporarily fulfilment, which take a life detached from the individual practitioner and operate as social agents who invite new forms of 'objectual sociality' (Knorr Cetina 1997). By this, she means that people become attached to the problems and objects they engage with in ways that create social ties and offer identities rather than cause individualization and alienation. As Knorr Cetina (2006, p. 32) states, knowledge objects should be understood "not only as the goal and target of professional work but as relational objects" which make relational demands and offer relational opportunities to those who deal with them. Examples of objects that may serve this function in professional and occupational work are computer programs in the field of software engineering (Knorr Cetina 2006), the market in the field of financial trading (Knorr Cetina and Bruegger 2002), and the concept of care in the field of nursing (Jensen and Lahn 2005). The ways and degree to which knowledge objects are represented in professional practice are constitutive of the knowledge culture. At the same time, the objects themselves emerge from expert cultures and incorporate significant features of the knowledge culture in play.

The present paper takes these perspectives as a point of departure in exploring the knowledge culture of computer engineering. In line with the above discussion, distinctive ways of producing, distributing and approaching knowledge within this field are explored and discussed as to how they offer opportunities for work-based learning. Then, the engineers' ways of being involved in learning are discussed more closely in relation to dynamics of objectual practice. The paper concludes by considering the character of this knowledge culture as regards some implications for individuals and communities. First, however, it provides a short description of the empirical study which underpins the discussion.

Data and Methodology

The discussion is based on data and ideas that have been generated in the Norwegian research project *Professional learning in a changing society*², which is a

² The project *Professional Learning in a Changing Society* is a 4-year study funded by the Research Council of Norway, carried out at the University of Oslo, Institute for Educational Research. More information is available at <http://www.pfi.uio.no/prolearn/>.

comparative study of learning in the transition from education to work among nurses, teachers, accountants and computer engineers. This paper, however, deals with the group of computer engineers only.

A qualitative approach was chosen in order to gain insights into how individuals engage with knowledge and learning related to their everyday work. A survey of students graduating from Oslo University College in 2002 (Studies of Recruitment and Qualifications in the Professions, 'StudData') was used as a basis for selection. Ten persons from each of the groups were chosen for participation, based on the following criteria: They were to have been working for approximately 2 years, their age was to be maximum 32 years, and the gendered sample was to correspond to the group's profile in the survey, still ensuring that the sample comprised minimum two participants from the gender in minority. Of those who met these criteria, the persons with the longer work experience were invited to participate in the study. As a result, our sample comprised three female and seven male computer engineers. They all hold a bachelor's degree in computer engineering; they are trained within the same professional programme, and share the history of being a member of this educational community. In working life, however, the participants represented an array of working sites, including the public as well as the private sector and a variety of firms.

Semi-structured in-depth interviews were conducted with each of the engineers during the spring 2005. Attention was focused on how the informants perceived and coped with shifting knowledge demands at work, as well as how these demands affected their work identity, commitment patterns, and engagement with diverse sources of professional knowledge. In addition, learning logs were utilized, in which the same participants recorded their experiences of learning needs during work over a period of 2×2 weeks, as well as their ways of dealing with these needs on a discretionary basis. About a year after the individual interviews were carried out we invited three of the participants to a focus group interview. This was organized as a facilitated discussion about the characteristics of their knowledge domain and working field as regards ways of organizing knowledge and knowledge development, approaches to learning in working life, and structures for career movements.

The individual interviews normally lasted 45–60 min, whilst the group interview lasted about 90 min. All interviews were tape-recorded and transcribed verbatim, and subjected to an inductive analysis facilitated by the scientific software ATLAS.ti. For this paper, the data was also examined with special attention paid to the above described dimensions of knowledge cultures. The learning logs were used as supplementary data to concretize themes from the interviews, in terms of identifying what kinds of questions were raised and what types of artefacts or knowledge sources the participants turned to in their efforts to dealing with experienced problems.

Despite the individual-oriented design and the diversity of workplaces represented in the data, our initial analyses pointed to a considerable degree of shared stories and experiences. Naturally, the particular qualities of working tasks and knowledge demands vary between different work contexts; however the individuals' narratives still reveal many common characteristics where the features of the professional knowledge domain are concerned. The analysis here gives emphasis to the shared stories and experiences rather than the differences between individuals when it comes to coping with the professional demands. The intention is not to neutralize the importance of individuals' different interpretations and strategies, but rather to

describe and discuss a domain of knowledge and expertise as it is experienced and comes to the fore in the narratives of practitioners. The interviewees are given fictitious names throughout the paper and all quotations are translated by the author. In addition to the interviews, the discussion draws upon an analysis of policy documents and recent debates within the relevant professional bodies in Norway (Karseth and Nerland 2007) as well as on previous research on workplace learning among engineers.

The Knowledge Culture of Computer Engineering

The empirical frame for the discussion is the working domain of computer engineers whose main tasks and functions are related to software development or to system administration. Although the division of labour in this professional field comprises a range of specialties both where expertise and working tasks are concerned, the ubiquitous presence of and interaction with technological objects is typical for this group. Such objects may for instance relate to a computer network in an organization, a programming language, or the user interface of electronic services provided by an organization. The constitutive power of the knowledge culture will be examined in terms of key characteristics that premise the knowledge practices in this field.

Professional Knowledge as Produced in Technological Markets

One distinctive feature of this knowledge culture is that notions of professional knowledge are closely linked to technological inventions and achievements. New computer programs, platforms and systems both premise the work of computer engineers and provide the foundation for the need of their expertise. Thus, to a large extent, the development of profession-specific knowledge pursues technological achievements. For the profession, this implies that the expert domain is characterised by dynamic interrelations towards other parts of the industrial sector, making market-orientation and cooperation an important dimension in efforts of advancement. For instance, the Norwegian Society of Engineers (NITO), the largest professional body for engineers and technologists in Norway, exemplifies this through linking support services to recent inventions and allocates its courses to firms and arenas in the technological working field (Karseth and Nerland 2007). NITO seems to advocate an epistementality where professional knowledge is regarded as produced in technological markets (*ibid.*). As a central agent in the field NITO's approach both reflects dominant modes of organizing knowledge in the profession and influences ways of engaging with knowledge among its members. The effects of this notion of knowledge production upon work-based learning are, however, not clear cut. While today's global markets might be said to undermine traditional professionalism based on jurisdiction within a certain field of expertise, they also require a widening of professional expertise along both vertical and horizontal dimensions (Beck and Young 2005). Further, the market regulation of the domain contributes to speed up technological turnovers and intensify the time and space relations of professional work. Some implications of these phenomena will be discussed below.

Knowledge as Information Distributed in Global Networks

The ways in which the professional practice is embedded in a knowledge economy serve to generate modes of knowledge distribution that goes beyond the boundaries of the profession. To a large extent, the epistemic infrastructures are given the character of information structures that are distributed in global networks, particularly by means of the Internet. Advancements in e.g. software or programming codes are made available on websites and accessed by professional engineers as well as by others. Since technologies are subject to rapid shifts and changes, such information structures are regarded as the most reliable source of updating. As one of our interviewees says about programming in the computer script Java:

In Java, for example all the information you need is on their homepage. If something new happens you will find it there. That's not the case in schoolbooks. (Peter, individual interview).

Information structures, such as web-based catalogues of procedures or best practices, provide a medium of transaction that cuts across institutional spaces and simultaneously allows for local embeddedness and global outreach (Knorr Cetina 2006). Thus, when practicing their work the practitioners are linked up with wider movements of knowledge development. Further, the network mode of organization implies that the logic of knowledge distribution is characterised by multiplicity and non-linearity (Castells 1996; van Loon 2006). A diversity of connections is possible, as the information provided could be accessed in different orders and in ways that disrupts any predetermined chronology of time. At the same time, the knowledge domain is subject to increasing differentiation that follows from a growth in the number of programming languages and technologies. As a consequence, the request for specialization is increasing and a range of sub-networks for different technologies are emerging. In this regard, the thematic structure of forums provides practitioners with opportunities for focused inquiries, as described by this engineer:

You find new knowledge on different websites where people have had the same problem as you before and where many have posted their solutions. I often look at the IRC chat program—the people who hang there know their stuff. It doesn't take long before you get an answer. (Peter, individual interview).

One implication of this mode of organizing knowledge practices is that there are close links between information structures and the application of knowledge in professional work. The information provided often has the character of codified procedures and recipes. The underlying logic reflects an epistementality that corresponds to what Schon describes as a *technical rationality*, in which practitioners are seen as “technical problem solvers who select technical means best suited to particular purposes” (Schon 1987, p. 3). Thus, the kind of learning offered when accessing networks of information is often restricted to updating the repertoire of programming skills and codified knowledge as part of the activity of identifying appropriate means to deal with particular problems.

Simultaneously, the connections between knowledge production and dissemination, and the way these processes are linked to global information structures and market interests, serve to involve professionals in structures of innovation that goes beyond localised problem solving. The interdependency between the production and

distribution of new technologies and the utilization and testing of such inventions in engineering practice gives rise to new arenas of participation where the traditional distinction between market and profession (Freidson 2001) is rather blurred. One example is the organization of knowledge dissemination at the website of Sun Developers Network (<http://developers.sun.com/>), a site that was mentioned as a main source of updating among our interviewees. Here, the producer of new technologies, Sun Microsystems, offers access to information and knowledge advancements by providing online courses, conferences, catalogues of programming patterns that are regarded to be “best practices”, as well as software that can be downloaded by developers worldwide. What is interesting to note is the ways in which such ways of structuring knowledge are linked to social structures of participation and community alignment. By means of weblogs, forums and discussion groups, members of the network are invited to share their personal as well as professional interests and to contribute to advancements in the field by testing technologies and sharing experiences. As Sun proclaims at one of their sub-sites for Java developers:

java.net provides a common area for interesting conversations and innovative development projects related to Java technology. By participating on java.net, members learn from each other, discover solutions to programming challenges, find new colleagues and mentors, and have more fun with Java technology. (<http://developers.sun.com/learning/academic/>, accessed January 2007).

Thus, while certainly providing information about advancements in the field, these kinds of networks also offer developers professional identities that are grounded in certain technologies and which exceed the local work settings. The learning professional is constructed as a member of a technological community who is encouraged to commit himself/herself to certain technologies and invited to contribute to the collective knowledge practices of the community. Moreover, the networks incorporate means for encouraging reciprocity and social commitment, for instance as described by one engineer with reference to one of the developer forums:

On their websites, you find something called DukeDollars—if you have a question you want answered you can use these. You just put three or four DukeDollars on the table and give these to the person that has the best answer. The other way around, you start with 25 dollars and if you want more you have to answer other people’s questions and then pile up more, and then you can get people to answer your questions again. I think it’s a neat system. (Martin, Individual interview).

For professionals as learners, the websites and information networks represent important arenas for sharing and updating their understanding of current software and technologies. These networks also constitute learning processes in particular ways by giving priority to the application of codified knowledge and technical skills, within predefined boundaries of specific technologies, and through patterns of interaction that mainly consist of structures of concrete questions and answers.

An Appeal to Standardization and Codified Procedures

A powerful dimension of the knowledge culture of computer engineering is the emphasis given to standardization of devices and codification of procedures.

Standards serve as a precondition that allows the network structures described above to be efficient. Moreover standardisation is closely interlinked with the technical rationality characteristic of the field. Informal standards come into view in the way engineers assess the work of colleagues and possible solutions. In spite of the multiplicity of possible connections and technical solutions, there are established principles for good engineering work. One interviewee describes it in the following way:

I believe it is more generally accepted in this field [than in others] what a good solution looks like. If five code developers work individually on the same task they will probable all agree – or at least four of the five will agree – upon which solution is the better. (Peter, individual interview).

Moreover, in approaching problem situations the engineers often turn to codified ‘best practices’ that are distributed in the information networks. They also embrace these patterns as models for their own work as developers. As Martin says, bearing the ideal-typical approach to work in mind; “when you face a new challenge, you will [try to] solve it in ways that are so good, so generic, so recyclable and effective that it could have served as a best practice” (group interview). Thus, approaches to accumulating knowledge in this professional domain, for instance through practices of developing and reprocessing programming codes, is closely linked to the development and distribution of standards that have a formal character. In contrast to many other arenas of everyday life, where individuals constantly engage with standards without paying any attention because they are so taken for granted in their social practices, computer engineers are dealing with standards in a very explicit manner. This is to a large extent what their work is about: Knowing the technological standards that are in play, knowing how they may work or not work together, and knowing how to perform different tasks within the different technological regimes. The commercial ways of advancing the knowledge domain by launching new versions of technologies serve to reinforce the importance of knowing and understanding the relevant standards (see also Loogma et al. 2004).

Accordingly, the technological standards are heavily present in the everyday language of computer engineers; in their ways of talking about their work, negotiating competence, and committing themselves to learning. For instance, our interviewees tell about how the discussion among developers during the first phase of a new project largely is about deciding which standards to use when approaching the present task or problem. This phase is often marked by energetic negotiations of preferences that have an emotional dimension. As Peter states; “discussions among developers are often somewhat heated, however, these disagreements are never long-lasting” (individual interview). What seems less discussed is the ways in which the ever-presence of standards influences upon the social practices in the profession, including practices of learning. Standards serve to create distinctions as regards competence, spaces for movements, differentiation of working tasks, and learning areas. Moreover, they serve to ‘make up’ kinds of engineers through their inscribed quests for specialization. In our data this comes into view in the ways in which some engineers identify with certain technologies and standards. For instance, one engineer talks about himself as a “J2EE developer” (Martin, individual interview), while another describes himself as “the Linux evangelist” in his workplace (Philip,

individual interview). The trend is also reflected in how employers tend to search for programmers who are specialized in certain technologies or programming languages.

This situation is both supportive and challenging for the engineers. Standards open and close possibilities at the same time. As one engineer expresses it, there is a danger that you “get squeezed if the short-term interests of your employer makes you less attractive on the labour market”, for instance if the technologies preferred by the employer turn to be out of date (Martin, Group interview). Thus, as also noted by Loogma et al. (2004), a strong identification with certain technologies and standards may serve to limit practitioners’ opportunities for career mobility.

The Creative Power of Indefinite Knowledge Objects

At the same time as the knowledge culture of computer engineering highlights the need for standards and consistency, the professional practice is characterised by engagements with artefacts that have an ambiguous and open-ended character. Systems, programs and codes can always be improved to be more efficient, more widely applicable, or more complex in their functionalities. In the moment of resolving a technical problem by means of e.g. applying distributed codes or patterns of practice, new possibilities and untried functionalities appear. The professional practice is thus characterised by a richness of epistemic objects. As noted above, epistemic objects are marked by their unfolding character and their lack of completeness of being. Such “objects of investigation” are “characteristically open, question-generating, and complex. They are processes and projectives rather than definitive things” (Knorr Cetina 2006, p. 33).

The presence of epistemic objects in a knowledge culture allows for an externalization of learning and knowledge engagements. This again constitutes the relationship between the knowledge domain and practitioners in certain ways, where objectual relationships – that is, the relational dynamics between humans and their non-human material – define the knowledge practices. Knorr Cetina (2001, 2002) uses computer programs as an example of objects that propel such dynamics by their way of being simultaneously both ready to be used and in a process of transformation. On the one hand, engineering work such as programming is heavily commodified and objectified in terms of standards, software and platforms that are defined and materialized as physical things. On the other hand, the technology and computing practices are continuously changing, thus resisting commodification. As Mackenzie (2005, p. 75) notes, an operating system is not “reducible to a conventional commodified object if it constantly modulates as it moves through a distributed collective of programmers and system administrators”. In a similar way, writing codes within a programming language implies both to move within conventional constraints and to make innovations based on them (Bowker and Star 2000, p. 159). Thus, the open-ended character of epistemic objects brings a creative dimension to work which may serve as a primary driving force in work-based learning (Jensen 2007).

As a consequence, it is not sufficient to understand the practice of computer engineers in terms of restricted problem solving and rule following. Engineering work also implies an interest of discovery and an ability to see the unfulfilled potential inherent in the technological scene. In a group interview, this issue came up as a topic when the engineers discussed how they face challenges when acting on the

basis of routines is not sufficient. One of them, who works as a software developer in a large consultant company, provided the following example:

In some cases, you have a customer who has a hybrid server park, and who, due to e.g. new ownership structures, has received the message that no more money will be spent on that equipment. Then you have to make sure that what you do is compatible between the different systems, which may not speak the same language. Such situations require a lot more creativity than just depending upon logic reasoning. You have to think broader and to think more freely than you would have done in a homogeneous technological environment. (Martin, Group interview).

The example points to how the application of standards is challenged by both the local context where technologies are situated and by the objects' inherent potential for change. The challenge presented to the practitioner corresponds to general descriptions of engineering work. As noted by Bucciarelli and Kuhn (1997, p. 211) engineers typically "go about making up scenarios about things and principles, physical concepts and variables and how they relate". However, while such activities require creativity, the aim of the scenario making is to achieve a closure by arriving at a solution that is "fixed, repeatable, stable, unambiguous, and internally consistent" (ibid, p. 212). Thus, there is a paradox between the specified and the ambiguous in this knowledge domain, where the practitioner becomes involved in learning by constantly moving between the unfulfilled and the temporarily fixed. This seems also valid for engineers who mainly do system administration. As one interviewee states;

In fact, the most important thing is to realise the potential of the system you are working with. As you learn more about it you also see many new opportunities. (Ina, individual interview)

For the professional, the dynamics of objectual relationships require an experimental attitude where the practitioner needs to be sensitive for the unfulfilled potential of the technology in question. That is, they need to be sufficiently familiar with the field of knowledge to be able to interpret objects in terms of their ways of displaying lack and to see their inherent potential for change (Knorr Cetina and Bruegger 2002). At the same time, the objects provide the learner with directions for further investigations, and in this way also with an energy and a "binding force" that may propel learning forward (Jensen and Lahn 2005; Jensen 2007).

Organizing Work as Restricted Series of Problem Solving

The ways in which the knowledge practices of everyday work are organized both reflects and constitutes the knowledge culture of the profession. As in engineering cultures, the domain of computer engineering is perhaps characterized by a dominant pragmatist way of thinking. This implies a high value placed on the application of knowledge in dealing with practical problems, a focus on validating theoretical principles through activities of inquiry, and an overall emphasis given to making things work and getting the task done. The problem-oriented approach implies that engineering work largely is organized as series of problem solving (Bucciarelli and Kuhn 1997; Collin 2005; Downey 1998; Sørensen 1998), either in terms of correcting malfunctions that occur in a technological system or in terms of

developing new functionalities in accordance with given specifications (data from learning logs).

With regards to the question of work-based learning, the regulation of the problem solving activities in time and space are important. The activities are characterised by restrictions in two ways. First, they are spatially limited in terms of *content*, as the engineers' responsibilities often are allocated to specific functions or parts of a project or a computer system. In larger firms, the practitioners are often organised in specific teams dealing with specific tasks that are linked together in a broader structure. For instance, one of our interviewees is based in a "user interface team" which develops functionalities that other teams use as a basis in their work:

My team and another team develop modules that the business teams utilize to develop their logic. (...) So, in a way we provide the framework, or the components that the other teams use to e.g. making screen images. (Richard, individual interview).

Within the team, the tasks are further specialized. In this case, the user interface team comprise one leader that specify the requests of the task; three code developers; one tester; and one person who is responsible for securing documentation (*ibid.*). This division of tasks and responsibilities serve to constitute the space of learning opportunities in ways that are both enabling and constraining. On the one hand, the engineers are involved in limited parts of the knowledge domain and are, therefore, exposed to limited opportunities for learning. On the other hand, they are provided with opportunities to specialize their skills in ways that might enhance the opportunities for focused learning. Further, the ways in which additive structures of accumulation are developed through cooperative efforts allow for a sense of meaningfulness in the performance of limited task. One engineer links this to the performative character of the knowledge practices:

You feel that you are part of a dynamic structure that, when working at its best, as it generally does, gives you an incredible feeling of satisfaction. Moreover, in my work situation you see the results of what you have done in a very, very explicit manner. That really gives you a good feeling. (David, individual interview).

Second, the problem solving activities are restricted in terms of *time*. The working days are often characterized by a series of 'short-term loops' where processes of inquiry and specific problem-solving coalesce. The quest for quick solutions and knowledge application may give priority to surface forms of learning and undermine possibilities for more profound engagements with knowledge. For instance, several engineers mention how they often must give priority to solve specific problems, and thus restrict their engagement with knowledge advancements to identifying and applying patterns that are ready at hand for making the technology work (group interview). Moreover, the dominant project organization characteristic for the field contributes to an intensification of time where the problems in question have to be resolved within a limited time frame (Davies and Mathieu 2005; Ó Riain 2000). In some cases, this may serve to undermine possibilities of work-based learning, as the timeframe does not allow for the development of new skills. In Ó Riain's (2000) ethnographic study of a software team, this restriction of opportunities came into view

when the team found themselves in need of new skills, and, due to time constraints, was forced to employ an external consultant with the necessary competency instead of training current employees. Also, in our data, the ways the tight schedules restrict opportunities for learning is a recurrent theme. Many of the interviewees stated they would have liked to engage more broadly in learning, but that the time pressure in their work makes it difficult. Thus, one consequence of these ways of organizing work might be that the responsibility for more profound knowledge engagements is allocated to the individual engineer and delegated to their time off work.

Learning as Engagement in Multiple Dynamics of Objectual Practice

More recent discussions within the field of professional and vocational learning display an increasing interest in the significance of epistemic tools and objects to learning (Billett 2004; Engeström 2004; Guile 2007; Lahn and Jensen 2006). The perspectives of Knorr Cetina (2001, 2006) highlight the interdependency between knowledge cultures and their practices, the knowledge objects created by and offered in these practices, and the role of knowledge objects in connecting individuals to the field of expertise. Thus, although issues of learning are not her main concern, her notion of objectual practice seems relevant for discussing work-based learning in object-rich domains.

The above described features of the knowledge culture of computer engineering serve to involve the practitioners in different dynamics of objectual relationships. First, the task-based organization of work and the emphasis given to standards and codified procedures relate everyday learning to practices of identifying apt standards and approaches to be applied in short-term loops of problem solving. For instance, as illustrated above, the engineers access web-based forums to get informed about advancements or to identify programming patterns that may be utilized in their current working tasks. In this context, the engineers engage with objects that embody knowledge in a variety of representational forms, comprising technical specifications; ‘best practices’ that derive from other practitioners’ problem solving and are circulated in the community through processes of codification; standardized methods for inquiry in relation to technological devices, and concepts for “naming and framing” the problem at hand (Schon 1987). Some objects have the character of being ‘ready-to-be-used’ and represents more permanent and repeatable forms of technological objects, e.g. written sequences of code that can be inserted directly into a programming task. These do not conform to the definition of epistemic objects proposed by Knorr Cetina. Other objects represent more ambiguous and open-ended epistemic objects that have the capacity to invite creative activities and deliberate learning. These objects may present themselves as separate artefacts, tasks or systems, such as the server park of a company or the interface of web-based bank services. However, they may also emerge as products of several well-defined technological objects that are combined in new ways, for instance in the context of a local project of software development.

In practice, however, the two types of objects depend upon each other and contribute jointly to learning and knowledge advancements. As noted by Miettinen and Virkkunen (2005) the well-defined and established objects that are ready-to-be-

used shape the realm of possible representations of an open-ended epistemic object. Drawing on Rheinberger (1997), they state that epistemic objects only can be understood “as part of historically evolved experimental systems or practices” (Miettinen and Virkkunen 2005, p. 438). Moreover, they claim, along with Rheinberger (1997), that the distinction between defined things and open-ended knowledge objects is functional in character. Thus, how we define the status of specific objects depends on their place and function in an experimental system. As noted earlier, many of the technological objects in computer engineering have the dual form of being simultaneously both ready-to-be-used and in-a-process-of-transformation (Knorr Cetina 2006). This duality provides rich opportunities for the engineers to be involved in series of object relations that move between confirming and experimental modes of practice. Moreover, this interplay between the fixed and the open-ended questions the general tendency within debates about professional learning to see technical rationality as obstructive and contradictory to experimental modes of practice. In this professional field, and due to the dual character of the knowledge objects, engagement with objects that are ‘ready to be used’ seems to provide a basis for learning in terms of inviting and encouraging experimental practice.

Second, the dynamics of objectual practice within this professional domain incorporate more long-term and future-oriented interests in learning. The rapid shifts in standards and generations of technologies make staying in touch with the ‘coming’ technology an important issue for the engineers, in order to be involved in relevant learning activities and secure their future positions in the labour market. As their working days are dominated by sequences of problem solving, the engineers need to activate other techniques to keep up with the advancements more broadly and to care for their long-term career interests. A common strategy in this respect is related to monitoring advancements in the technological field. When the practitioners engaged with new tasks and technologies as part of their problem solving activities, they simultaneously employ techniques for staying informed on what’s happening and for involving themselves in future scenarios. One engineer describes how he acts when new technological opportunities present themselves during work:

It is extremely important to... have an idea of what’s happening. So, you keep an eye on it, but you don’t really go into it. Perhaps you try it out for ten minutes or so, just to see what it is, and then you put it aside. But then you know that the next time I face this kind of question I will have a closer look at it. (...) So, very often, at least as I experience it, you try to see what’s coming up in say the next six months. And after a while, when you have finished what you were working on and stand in front of new tasks you may take it into use. (Peter, Group interview).

These kinds of objectual practice encompass engagements in learning also when off work, with an eye to delayed realizations of the not-yet-fulfilled. Moreover, deliberate learning in computer engineering seems to be tightly interlinked with career management³, in which the notion of career may turn into an object itself (cf.

³ At a collective level this is manifested in the ways the Norwegian Society of Engineers (NITO) attempt to support its members by offering services of career consultancy. On their website these services are organized under the joint heading ‘courses and career’, because, as NITO states, “career is about being a lifelong learner throughout working life” (www.nito.no, accessed June 2007, author’s translation).

Brown 2004; Grey 1994; Loogma et al. 2004). Nevertheless, it is heavily dependent upon other epistemic objects, which constitute the basis for career ambitions (Miettinen 2005) at the same time as these aspirations mobilize practitioners to engage in continual inquiries into specific technologies.

As shown above, the dynamics of objectual relationships in computer engineering play out within different frames of space and time. However, they also coexist in interesting ways. One epistemic object may take the position as object of instant inquiries and at the same time serve as a stepping stone for future explorative activities. Furthermore, it may serve as a mediating tool for the exploration of other objects. Thus, as regards the epistemic objects provided in this knowledge culture, two dimensions of simultaneity come to the fore: For one, the objects often have the dual character of being both ready at hand and in process of transformation. Second, they may take a dual position as partakers in short-term cycles of problem solving at the same time as they lead into long-term series of career movement.

Together with the other characteristics of this knowledge culture, the different roles of the objects involve the practitioners in multiple and coexisting dynamics of objectual practice.

The epistemic infrastructures offer opportunities for expansive inquiries and may contribute to establishing permanent structures of wanting among the practitioners (Jensen 2007). Yet, the different objects may also come in conflict and create tensions between different needs and requests. As one of our interviewees expressed:

I regard my career as consisting of at least two tracks... one in the [name of firm] where I am currently employed... and one more lifelong career. And the two of them do not always have shared interests. (Martin, Group interview).

Thus, the knowledge culture of computer engineering is also marked by an individualization of responsibilities for negotiating between the different concerns. Professionals within this field of expertise need to develop strategies for navigating in the landscape of multiple and ambiguous object relations. While the perspectives of Knorr Cetina (1997, 2001) highlight how epistemic objects may encourage inquiries beyond the present and provide individuals with opportunities for ‘looping their desire through the object and back’, her theories are less helpful in describing how the engineers decide upon what desire should be given priority when conflicts arise.

Concluding Remarks

This paper has portrayed distinctive characteristics of the knowledge culture of computer engineering and examined how profession-specific ways of organizing knowledge practices in this field serve to shape opportunities for work-based learning. In particular, the paper has pointed to how the rich provision of knowledge objects in this culture involves the engineers in multiple and coexisting dynamics of objectual practice that play out within different frames of space and time. The emphasis given to problem-solving in terms of correcting malfunctions or developing new functionalities seems to involve the practitioners in short-term loops of problem-driven learning. Parallel to this, the engineers monitor the technological advancements in the field more broadly and actively use their

everyday involvement with objects to feed into series of long-term career movements. In both cases, objectual relationships seem important for their ways of navigating in their professional landscape. These relationships provide resources for learning in ways that questions the tendency to see technical rationality as obstructive and contradictory to experimental modes of practice. At the same time, they present challenges to individuals and communities. In order to reveal how the objectual dynamics actually play out and are negotiated in professional practice, further research into the knowledge objects themselves, as well as the chains of activities they generate, is needed. This paper concludes by raising two issues of concern that emerge from our data and that resemble issues addressed in other studies.

First, despite of the rich provision of shared practices, artefacts and objects, the knowledge culture of computer engineering seems to allocate extensive responsibilities for professional development to the individual practitioner. This is partly related to the ways in which learning is incorporated in everyday work and integrated in specialized tasks, which may make learning an epiphenomenon of the division of labour and the problem settings at hand. Concurrently, the rapid shifts in technologies and work structures contribute to individualise the responsibility for long-term competence development. This profession is generally characterized by high mobility and by an absence of set career paths (Davies and Mathieu 2005; Loogma et al. 2004; Ó Riain 2000), and in some ways the production context resembles that of “moebius strip enterprises” (Guile 2007) in the request for being able to reorganize quickly to respond to changing market conditions. As a consequence, the learning demands include requests for what Castells (2000, p. 1) has called ‘self-programmable labour’. That is, “labour which is sufficiently flexible, technically equipped, and well trained to be able to adapt itself throughout its professional life to different tasks, contexts and requirements” (ibid.). Earlier research among IT workers has also indicated that practitioners in this field take quite different choices and move along different professional trajectories (Billett et al. 2005) and that the demands for being both flexible and ‘technically equipped’ may cause tensions and dilemmas for practitioners to deal with (Loogma et al. 2004).

These circumstances call for extensive skills in reflexivity and self-management. Further, the requests for both committing to the lacks and needs in current working tasks and to managing ones own working career by engaging in broader activities of continuous learning may give the professional practice an intensive character. In general, this professional domain is characterized by high turnovers and by a young working force. It is however uncertain whether the high turnover is caused by time compression and rapid shifts in technologies alone. Alternatively, it might be that the implicit requests for constantly utilizing everyday learning experiences to feed into cycles of long-term career movements contribute to tiredness and burnouts. Thus, the ways in which practitioners act on themselves and negotiate between different concerns need further investigation.

Second, in a professional knowledge culture characterized by a richness of epistemic objects, an important learning issue relates to the type of knowledge practices and structures mediated by the objects. While the programmes for initial professional education typically highlight the need of grounding engineering work in profound insights in the natural sciences (Bucciarelli 2003; General plan for the bachelor’s degree in engineering in Norway 2003), our data indicate that these forms

of engagement with subject-matter knowledge are sparsely represented in object-related activities in working life. Thus, there is a danger that learning related to exploring subject-specific knowledge structures are left behind in favour of more compliant learning of technology-based knowledge. The time compression and rapid shifts characteristic for the field may also contribute to an overall 'depthlessness' and patterns of moving on the surface often associated with the age of post modernity (Jameson 1991). These issues may be explored in further research by paying attention to the character of concrete knowledge objects. However, as pointed out by Wertsch (1998) and Billett et al. (2005), deeper learning in terms of appropriation is a prerequisite for individuals to take command over their knowledge engagements and to transform their practices as new needs arise. Practitioners who mainly engage themselves in more surface-level engagement with technological advancements may be dragged into a spiral of increasing demands for technology-specific competence which may be progressively difficult to live up to. Thus, one way forward for the profession of computer engineering may concern the development of knowledge objects that mediate and invite exploration into wider knowledge spheres.

Together, these concerns indicate that the knowledge culture of computer engineering may benefit from paying more attention to profession-specific issues as a way of supporting learning and professional development in working life. As a domain of expertise that is positioned in close relations to the dynamics of the knowledge economy, the advancements of the professional knowledge domain will inevitably be linked to knowledge production in broader technological markets. Thus, professional jurisdiction in the field is likely to be both inefficient and impossible, as the professional demands to a great extent will pursue and be defined by technological advancements. Nevertheless, there are tendencies in the field that indicate a concern for establishing profession-specific intermediary associations and support structures, for instance as initiated by Thompson and Edwards (2001). This more articulated concern for professionalism might serve to reduce complexity and function as a stabilizing force in the somewhat unfilled space between the dynamics of global knowledge advancements and the learning practices of individuals.

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References

- Becher, T., & Trowler, P. R. (2001). *Academic tribes and territories: intellectual inquiry and the cultures of disciplines*. Buckingham: Society for Research into Higher Education/Open University Press.
- Beck, J., & Young, M. (2005). The assault on the professions and the restructuring of academic and professional identities—a Bernsteinian analysis. *British Journal of Sociology of Education*, 26(2), 183–199.
- Billett, S. (2004). Learning through work: participatory practices. In H. Rainbird, A. Fuller, & A. Munro (Eds.) *Workplace learning in context* (pp. 109–125). London: Routledge.
- Billett, S., Smith, S., & Barker, M. (2005). Understanding work, learning and the remaking of cultural practices. *Studies in Continuing Education*, 27(3), 219–237.
- Bowker, G., & Star, S. L. (2000). Invisible mediators of action: classification and the ubiquity of standards. *Mind, Culture, and Activity*, 7(1&2), 147–163.

- Brint, S. (2001). Professionals and the 'knowledge economy': rethinking the theory of postindustrial society. *Current Sociology*, 49(4), 101–132.
- Brown, A. (2004). Engineering identities. *Career Development International*, 9(3), 245–273.
- Bucciarelli, L. L. (2003). Designing and learning: a disjunction in contexts. *Design Studies*, 24(3), 295–311.
- Bucciarelli, L. L., & Kuhn, S. (1997). Engineering education and engineering practice: improving the fit. In S. Barley, & J. Orr (Eds.) *Between craft and science: technical work in U.S. setting* (pp. 210–229). Ithaca/London: Cornell University Press.
- Castells, M. (1996). *The rise of the network society*. Oxford: Blackwell.
- Castells, M., (2000). The institutions of the new economy. Summary of the address to the conference 'Delivering the Virtual Promise?', London, June 2000. Available online at <http://virtualsociety.sbs.ox.ac.uk/text/events/castells.htm>. Cited 10 May 2007.
- Collin, K. (2005). *Experience and shared practice—design engineers' learning at work*. Jyväskylä Studies in Education, Psychology and Social Research, 261. Jyväskylä: University of Jyväskylä. Available online at <http://julkaisut.jyu.fi/?id=951-39-2188-3>. Cited 15 Nov 2007.
- Davies, K., & Mathieu, C. (2005). *Gender inequality in the IT sector in Sweden and Ireland*. Stockholm: National Institute for Working Life.
- Downey, G. L. (1998). *The machine in Me: An anthropologist sits among computer engineers*. New York: Routledge.
- Edwards, R. (2004). Mobilising concepts: Intellectual technologies in the ordering of learning societies. *Pedagogy, Culture and Society*, 12(3), 433–448.
- Engeström, Y. (2004). The new generation of expertise: seven theses. In H. Rainbird, A. Fuller, & A. Munro (Eds.) *Workplace learning in context* (pp. 145–165). London: Routledge.
- Eraut, M. (2000). Non-formal learning and tacit knowledge in professional work. *British Journal of Educational Psychology*, 70, 113–136.
- Eraut, M. (2006). Professional knowledge and learning at work. *Knowledge, work & society*, 4(3), 43–62.
- Freidson, E. (2001). *Professionalism: the third logic*. London: Polity.
- Friedman, A., & Phillips, M. (2004). Continuing professional development: developing a vision. *Journal of Education and Work*, 17(3), 361–376.
- General plan: The bachelor's degree in engineering* (2003). Oslo: Norwegian Ministry of Education and Research.
- Grey, C. (1994). Career as a project of the self and labour process discipline. *Sociology*, 28(2), 479–497.
- Guile, D. (2007). Moebius strip enterprise and expertise in the creative industries: new challenges for lifelong learning? *International Journal of Lifelong Education*, 26(3), 241–261.
- Jameson, F. (1991). *Postmodernism or the cultural logic of late capitalism*. London: Verso.
- Jensen, K., & Lahn, L. (2005). The binding role of knowledge: an analysis of nursing students' knowledge ties. *Journal of Education and Work*, 18(3), 305–320.
- Jensen, K. (2007). The desire to learn: an analysis of knowledge-seeking practices among professionals. *Oxford Review of Education*, 33(4), 489–502.
- Karseth, B., & Nerland, M. (2007). Building professionalism in a knowledge society: examining discourses of knowledge in four professional associations. *Journal of Education and Work*, 20(4), 335–355.
- Knorr Cetina, K. (1997). Sociality with objects: social relations in post-social knowledge societies. *Theory, Culture and Society*, 14(4), 1–30.
- Knorr Cetina, K. (1999). *Epistemic cultures*. Cambridge, MA: Harvard University Press.
- Knorr Cetina, K. (2001). Objectual practice. In T. Schatzki, K. Knorr Cetina, & E. von Savigny (Eds.) *The practice turn in contemporary theory* (pp. 175–188). London: Routledge.
- Knorr Cetina, K. (2002). Transitions in post-social knowledge societies. In E. Ben Rafael, & Y. Sternberg (Eds.) *Identity, culture, and globalization* (pp. 611–628). Leiden: Brill Academic Publishers.
- Knorr Cetina, K. (2006). Knowledge in a knowledge society: Five transitions. *Knowledge, Work and Society*, 4(3), 23–41.
- Knorr Cetina, K., & Bruegger, U. (2002). Traders' engagement with markets—a postsocial relationship. *Theory, Culture & Society*, 19, 161–185.
- Lahn, L., & Jensen, K. (2006). Models of professional learning. Exploring the epistemic tool perspective. *Knowledge, Work and Society*, 4(3), 63–82.
- Loogna, K., Ümarik, M., & Vilu, R. (2004). Identification-flexibility dilemma of IT specialists. *Career Development International*, 9(3), 323–348.
- Mackenzie, A. (2005). The performativity of code: software and cultures of circulation. *Theory, Culture & Society*, 22(1), 71–92.

- Miettinen, R. (2005). Object of activity and individual motivation. *Mind, Culture, and Activity*, 12(1), 52–69.
- Miettinen, R., & Virkkunen, J. (2005). Epistemic objects, artefacts and organizational change. *Organization*, 12(3), 437–456.
- Nerland, M., & Jensen, K. (2007). Insourcing the management of knowledge and occupational control: an analysis of computer engineers in Norway. *International Journal of Lifelong Education*, 26(3), 263–278.
- Nespor, J. (1994). *Knowledge in motion. Space, time and curriculum in undergraduate physics and management*. London: Falmer.
- Olssen, M. (2006). Understanding the mechanisms of neoliberal control: lifelong learning, flexibility and knowledge capitalism. *International Journal of Lifelong Education*, 25(3), 213–230.
- Ó Riain, S. (2000). Net-working for a living: Irish software developers in the global workplace. In M. Burawoy, J. A. Blum, S. George, Z. Gille, T. Gowan, L. Haney, M. Klawiter, S. H. Lopez, S. Ó Riain, & M. Thayer (Eds.) *Global ethnography: forces, connections, and imaginations in a postmodern world* (pp. 175–202). Berkeley: University of California Press.
- Rheinberger, H.-J. (1997). *Toward a history of epistemic things: synthesizing proteins in the test tube*. Stanford: Stanford University Press.
- Schon, D. A. (1987). *Educating the reflective practitioner*. San Francisco: Jossey-Bass.
- Sørensen, K.H., ed. (1998). *The spectre of participation: technology and work in the welfare state*. Oslo: Scandinavian University Press.
- Thompson, J. B., & Edwards, H. M. (2001). Achieving a world-wide software engineering profession: a report on the CSEET 2001 workshop. *Education and Information Technologies*, 6(4), 267–293.
- Tuschling, A., & Engemann, C. (2006). From education to lifelong learning: the emerging regime of learning in the European Union. *Educational Philosophy and Theory*, 38(4), 451–469.
- Usher, R., & Solomon, N. (2001). Experiential learning and the shaping of subjectivity in the workplace. *Studies in the Education of Adults*, 31(2), 155–163.
- Van Loon, J. (2006). Network. *Theory, Culture & Society*, 23(2–3), 307–322 (Special encyclopedia issue: Problematizing Global Knowledge).
- Wertsch, J. V. (1998). *Mind as action*. New York: Oxford University Press.

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